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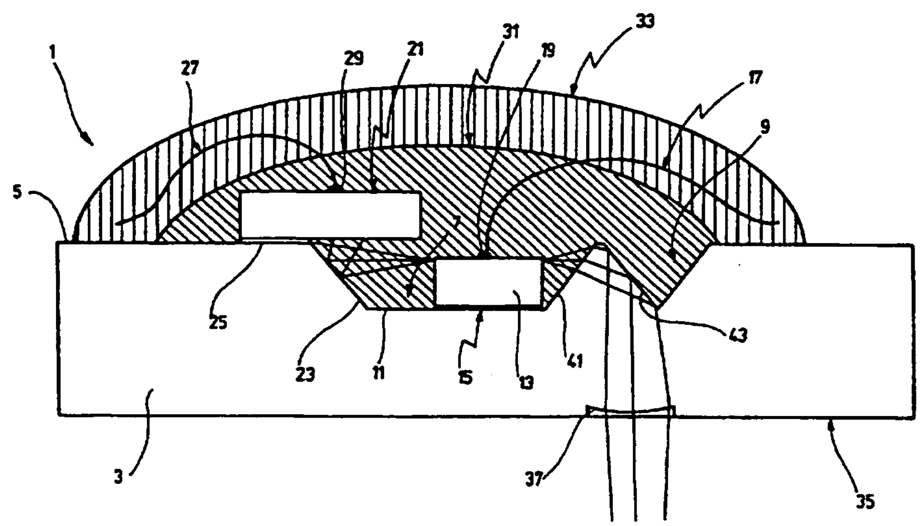
(54) **Encapsulating semiconductor optical devices**

(57) A semi conductor laser diode 13 and a photodiode 21 are mounted on one side of a transparent substrate 3. An optically transparent layer 31 encapsulates the diodes and a further layer 33 serves as a moisture barrier. A prism formed in the substrate directs a beam from the laser via a wall 43 and a lens 37 to an optical fibre. A wall 23 directs a beam from the laser to the photodiode for monitoring the operation of the laser diode.



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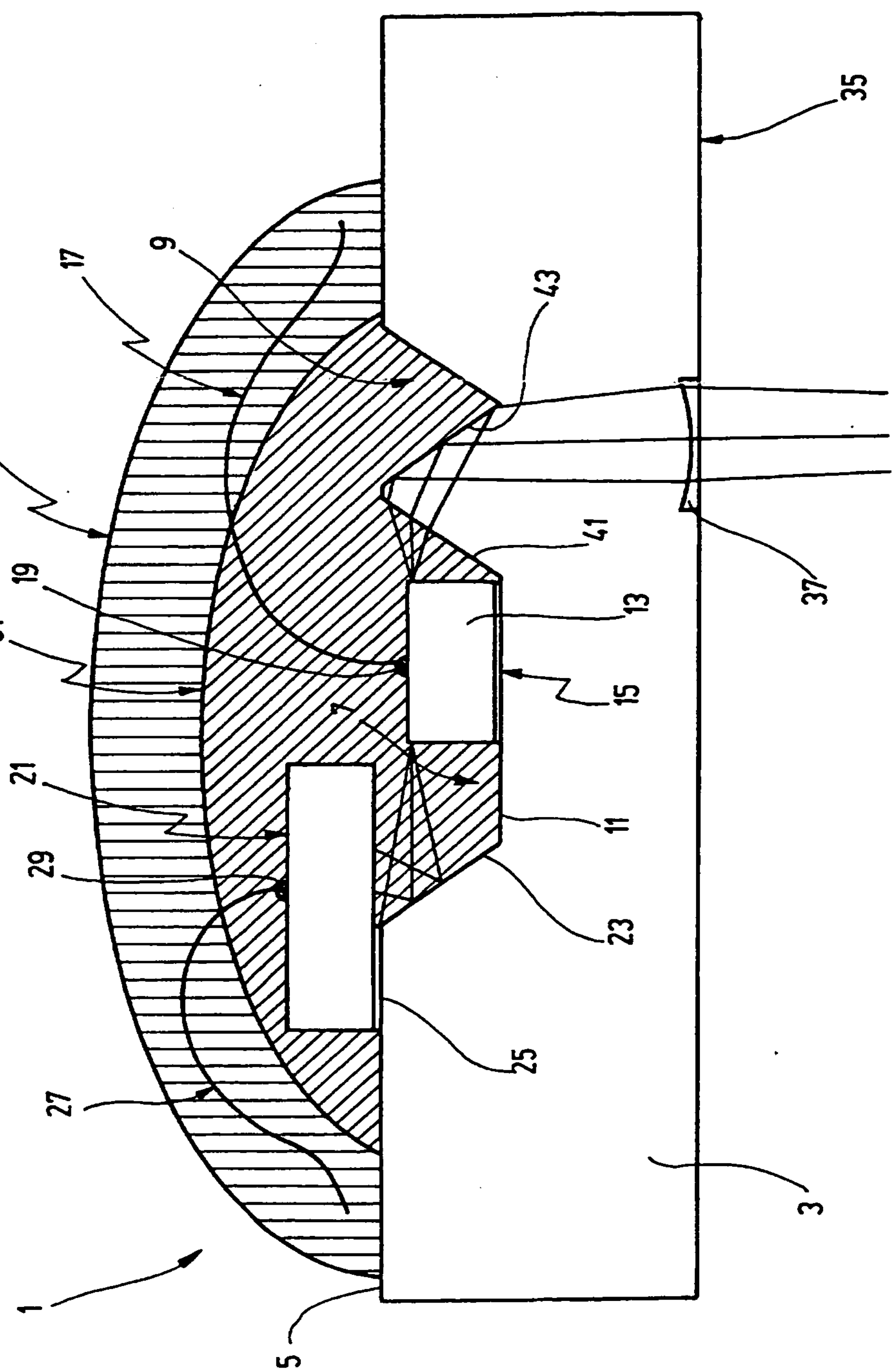
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Optical module for coupling an optical fibre and method of producing it

State of the art

The invention relates to an optical module for coupling an optical fibre with a translucent carrier and a transmitting or receiving element which is applied to a first side of the carrier. The invention also relates to a method of producing such an optical module.

A module of this type is known, for example, from the document DE 43 01 456 C1. The plate-shaped carrier made of silicon described therein is structured precisely by micromechanical production methods so a laser chip serving as a transmission element, an optical fibre and an imaging lens can be positioned with close tolerances. The final adjustment of the optical fibre of the laser chip is clearly simplified owing to the precise structuring. To protect the very sensitive laser chip from external influences, the laser chip is surrounded by a housing-like hermetically sealed arrangement, the carrier being part of the housing.

It is generally necessary in any case to install such semiconductor components, which are to be used, in a suitable housing to which the optical fibre is to be optically coupled. The protection of the components from environmental influences and a good optical coupling, in particular, play a decisive part in the design of the housing. The coupling is generally produced by an arrangement of one to two lenses, the position of the optical fibres relative to the lenses and the laser chip being optimised in an adjustment process. The laser chip is arranged in a housing which is hermetically sealed from the environment, the lenses and the optical fibre being arranged either outside or in the housing. In the latter case, the optical fibre is conveyed from the housing through a hermetic bushing.

Scanning units are known from the sphere of CD devices, in which only the laser chip together with a photodiode is mounted in a hermetically sealed round housing for the monitoring of performance. This module is in the meantime also used for information transmission. The so-called coaxial housing used is a precision mechanical product made of metal and glass and - measured against the tolerance requirements for the optical coupling between laser and optical fibre in the range of below 1 μm - has very considerable production tolerances which is why a complex three-dimensional adjustment process is required to optimise the optical fibre coupling.

A drawback of the discussed use of a hermetically sealed housing is, in particular, that the costs incurred are becoming more significant as semiconductor prices fall.

The article "Pig-tail Type Laser Modules Entirely Moulded in Plastic" Electronics Letters, 28th September 1995, vol. 31, No. 20, pages 1745 to 1747 discloses an arrangement in which a laser diode is protected from environmental influences by a plastic moulding composition. A drawback is that the laser diode is coupled to the glass fibre without imaging lens by abutment.

Advantages of the invention

The method according to the invention with the features of claim 1 has the advantage that an expensive housing hermetically sealing the transmitting or receiving element can be dispensed with without losing protection from environmental influences, for example moisture. Since a translucent layer, for example an optically transparent moulding composition, is applied to the carrier and the transmitting or receiving element, the transmitting or receiving element is sealed from the exterior on the one hand by the carrier itself and on the other hand by the applied layer.

A trough-shaped recess is preferably formed on one side of the carrier, into which the transmitting or receiving element is preferably applied by means of a soldered joint, so additional protection is afforded.

A further layer which acts as a moisture barrier is preferably applied to the first layer. By means of this two-layered construction, optimisation of the first layer with respect to the optical effect and of the second layer with respect to the screening effect can be achieved better.

A lens which allows better efficiency of coupling during the coupling of an optical fibre than an abutment is preferably formed on the other side of the carrier.

The optical module according to the invention for coupling an optical fibre having the features of claim 7 also has the advantage that a housing which hermetically seals the transmitting or receiving element is not required. An optically translucent layer which essentially surrounds the transmitting or receiving element and therefore screens it from the exterior does in fact protect the sensitive transmitting or receiving element, preferably a laser diode, from external environmental influences.

The transmitting or receiving element is preferably arranged in a trough-shaped recess, of which the beam path is directed to an oblique wall of the recess and is conveyed to the underside of the carrier via a reflective surface formed in the carrier.

To increase the efficiency of coupling, a lens is preferably provided in the beam path on this underside.

In a development of the invention, the transmitting or receiving element, preferably a laser diode, is allocated a monitor photodiode, which is also surrounded by the first layer and by means of which the laser diode can be monitored.

Further advantageous embodiments of the invention will emerge from the remaining sub-claims.

Drawings

The invention will now be described in detail with reference to the drawing which relates to an embodiment. The single figure is a schematic sectional view of an optical module.

Description of an embodiment

The figure shows an optical module 1 comprising a carrier plate 3 preferably consisting of silicon.

A trough-shaped recess 7 and a V-shaped groove 9 adjacent thereto are introduced on an upper side 5 of the carrier plate 3 by a wet chemical etching process.

A semiconductor laser diode 13 is placed on a base 11 of the recess 7, a layer of solder 15 being used to produce the connection. The laser diode 13 itself is activated via an electric lead 17 arranged on a contact point 19.

A monitor photodiode 21 is arranged on the upper side 5 of the carrier 3 adjacent to the laser diode 13. The monitor photodiode 21 is orientated relative to an oblique lateral surface 23 of the recess 7 in order thus to be able to absorb light reflected therefrom. However, the monitor photodiode 21 is fastened on the plane

upper side 5 of the carrier 3, a layer of solder 25 again being used. A conductive adhesive can obviously also be used instead of the solder. The signals emitted by the photodiode 21 are transmitted via an electric lead 27, connected to the photodiode at a contact point 29, to a subsequent control and evaluating unit, not shown.

The figure also shows a layer 31 which completely surrounds both the photodiode 21 and the laser diode 13. Only the connecting faces to the upper side 5 of the carrier plate 3 do not come into contact with this layer 31. The groove 9 is also filled by the layer 31.

The layer 31 consists of an optically transparent material having a defined optical refractive index which is important for calculating the beam path described hereinafter.

A further layer 33 serving as a moisture barrier is applied to the dome-shaped surface of the layer 31. This two-layered construction is used whenever the optically transparent layer has inadequate moisture-proofing properties.

The laser diode 13 which is very sensitive to external influences can easily be protected by the two layers 31 and 33.

It can also be inferred from the figure that an optical lens 37 which improves the coupling of the laser light into an attached optical fibre is formed on an underside 35 of the carrier plate 3.

An optical module 1 is produced in several stages, a silicon wafer being used as basic material. Recesses 7 and 9 are initially formed by wet chemical etching in the surface of the carrier plate 3 consisting of silicon, the oblique walls 23 being

defined by the crystal direction and their position and size therefore having precision of the order of 1 μm.

The laser diode 13 is then introduced into the recess 7, for which purpose the solder 15 is heated spot-wise, for example with a NdYAG laser.

The laser diode is preferably orientated within the recess 7 in the longitudinal direction on the edge of the transition of an oblique wall 41 into the base 11 of the recess 7. Markings can additionally be provided for adjustment on the upper side 5 of the carrier plate 3.

Before application of the laser diode, a gold layer can additionally be applied to parts of the surface 5 to improve electrical contact with the carrier plate 3. In addition to improving the electrical conductivity, this gold layer - not shown in the figure - acts as a reflector, for example on the oblique wall 23.

The interfaces of the carrier plate 3 at which light enters or issues are provided with a non-reflective layer, for which a quarter wavelength layer having a suitable refractive index deposited over the entire face on both sides 5 and 35 suffices.

When both photodiode 21 and laser diode 13 are applied, the layer 31 is initially applied and then the outer moisture-proofing layer 33.

A lacquer lens, produced by photolithography and melting of the lacquer, is transferred into the silicon to form the lens 37. A further possibility is to form a lens by etching a trough-shaped recess and self-adjusted introduction of a glass bead. Individual adjustment is unnecessary in both cases, so the adjustment process only takes place once during production of the carrier plate.

The individual optical modules 1 formed on a wafer are finally separated by sawing or breaking. The laser diode 13 is undamaged owing to the layers 31 and 33 and the recessed arrangement of the laser diode 13. The underside 35 can be protected with a lacquer layer before separation in order to provide protection from impurities.

Additional adjustment marks which serve for pre-orientation during the final optical coupling of the separated modules with the optical fibre arranged, for example, on a similar carrier plate can also be applied on the underside 35 during production so the necessary adjustment process is simplified and accelerated.

Operation of the optical module will now be described briefly hereinafter.

The laser diode 13 emits laser light in a wavelength range above 1100 nm in the direction of the oblique wall 41 of the recess 7. Owing to the optical transparency for this wavelength range of the layer 31, the beams reach the wall 41 where they are refracted vertically. However, this is conditional on the material of the layer 31 having an appropriate refractive index. The light is then propagated within the carrier plate 3, which is also translucent for the specified wavelength range, and impinges on an oblique wall 43 of the V-shaped groove 9. The light is then reflected downwardly there to the underside 35. Once it has passed through the carrier plate 3, it issues at the underside 35. If the laser light is then to be coupled into an optical fibre or to be used as a collimated beam, the lens 37 is arranged at the outlet point.

To monitor operation of the laser diode 13 and to control the output power in the event of temperature changes and ageing, the laser diode 13 irradiates light to the oblique wall 23 at which it is reflected toward the photodiode 21.

The material of the layer 31 is particularly important in this optical module. As already mentioned, it has to have a defined refractive index which is also constant and reproducible. It also has to be free from stray centres caused, for example, by fillers and to have high transparency at the emission wavelength of the laser diode 13. Finally, it is also necessary for the material to have low thermal expansion.

In an embodiment of the invention, not shown, the recess 7 is made in two stages. The laser chip 13 is mounted on the base 11 of the higher stage such that the light-emitting region rests directly on the solder layer (Epi-down mounting). The end face simultaneously rests at the edge of the transition from the higher to the lower stage so light is initially also emitted into the space filled by the layer 31 before it passes into the carrier at the oblique lateral wall 41. The distance between the laser diode 13 and the lateral wall 41 can be smaller in this arrangement and this may be advantageous for laser diodes with a large opening angle of emission.

Claims

1. Method of producing an optical module suitable for coupling an optical fibre with at least one transmitting or receiving element which is placed on a first side of a transparent carrier, a beam path extending from the transmitting or receiving element to the opposite side of the carrier, characterised in that an optically transparent layer which surrounds at least the transmitting or receiving element is applied.

2. Method according to claim 1, characterised in that a preferably trough-shaped recess into which the transmitting or receiving element is inserted is formed on the first side of the carrier.

3. Method according to claim 1 or 2, characterised in that a further layer (33) which serves as a moisture barrier is applied to the optically transparent layer (31).

4. Method according to one of the preceding claims, characterised in that the transmitting or receiving element is connected to the carrier by a solder layer.

5. Method according to one of the preceding claims, characterised in that a lacquer lens is transferred into the carrier on the second side (35) of the carrier (3), the lacquer lens being produced by a photolithographic process and subsequent melting of the lacquer.

6. Method according to claim 2, characterised in that the recess is produced by a wet chemical etching process.

7. Optical module for coupling an optical fibre, with a translucent carrier (3) and a transmitting or receiving element (13) which is applied to a first side (5) of

the carrier (3), characterised by an optically transparent layer (31) which surrounds at least the transmitting or receiving element (13).

8. Optical module according to claim 7, characterised in that the carrier (3) has, on the first side, at least one preferably trough-shaped recess (7) into which the transmitting or receiving element (13) is introduced, the beam path of the transmitting or receiving element being directed to an oblique lateral wall (41) of the recess (7).

9. Optical module according to claim 6 or 7, characterised in that, adjacent to the oblique lateral wall (41) of the recess (7) there is provided a preferably V-shaped groove (9) of which one wall (43) lies in the beam path as a reflective face.

10. Optical module according to one of claims 6 to 9, characterised in that a lens (37) is provided on a second side (35) of the carrier (3) opposite the first side.

11. Optical module according to one of claims 7 to 10, characterised in that a further layer (33) which acts as a moisture barrier is formed on the external surface of the first layer (31).

12. Optical module according to one of claims 7 to 11, characterised in that the material of the carrier (3) is silicon.

13. Optical module according to one of claims 7 to 12, characterised in that the material of the first layer (31) is organic.

14. Optical module according to one of claims 7 to 13, characterised in that the transmitting or receiving element is a semiconductor laser diode which emits light in the wavelength range above 1100 nm.

15. Optical module according to claim 14, characterised in that the laser diode (13) emits light in an opening angle of 10° to 50°.

16. Optical module according to claim 14 or 15, characterised in that the laser diode (13) is allocated a monitor photodiode (21) which is formed on the first side (5) of the carrier (3) and is also surrounded by the first layer (31), for the monitoring thereof.

17. Optical module according to one of claims 7 to 16, characterised in that markings are formed on the first and/or second side for adjustment.

18. Optical module according to one of claims 7 to 17, characterised in that the first and/or second side of the carrier (3) is provided with a non-reflective layer.

19. Method of producing an optical module substantially as hereinbefore described with reference to the accompanying drawing.

20. Optical module substantially as hereinbefore described with reference to the accompanying drawing.

The Patent Office

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Claims searched: All

Examiner: C.D.Stone
Date of search: 7 July 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H1K(KQD,KED,KQAME,KPF);G2J(JGED)

Int Cl (Ed.6): H01L;G02B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	EP 0690515 A1	EASTMAN KODAK (See transparent substrate 12)	1,7
Y	EP 0081827 A2	SANYO (See transparent substrate 1,Fig.1)	1,7
Y	US 5226052	ROHM (See transparent resin 32,Fig.4)	1,7

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		